DESCRIPTION

HEAT EXCHANGER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is an application filed under 35 U.S.C. §111(a) claiming the benefit pursuant to 35 U.S.C. §119(e)(1) of the filing dates of Provisional Applications No. 60/580,718, and No. 60/659,902 filed June 21, 2004 and March 10, 2005, respectively, pursuant to 35 U.S.C. §111(b).

TECHNICAL FIELD

The present invention relates to heat exchangers, and more particularly to heat exchangers which are suitable to use as evaporators of supercritical refrigeration cycles wherein a supercritical refrigerant, such as CO_2 (carbon dioxide) refrigerant, is used.

The term "aluminum" as used herein and in the appended claims includes aluminum alloys in addition to pure aluminum. The upper, lower, left-hand and right-hand sides of FIGS. 1 and 2 will be referred to herein and in the appended claims as "upper," "lower," "left" and "right," respectively. Further the downstream side (the direction indicated by the arrow X in FIGS. 1 and 9) of flow of air through an air passing clearance between each adjacent pair of heat exchange tubes will be referred to as the "front," and the opposite side as the "rear."

BACKGROUND ART

Already known for use in supercritical refrigeration cycles is a heat exchanger comprising a pair of header tanks arranged as spaced apart from each other, heat exchange tubes arranged in parallel at a spacing between the pair of header tanks and having opposite ends joined to the respective header tanks, and fins arranged in respective air passing clearances between respective adjacent pairs of heat exchange tubes and each brazed to the tubes adjacent thereto, each of the header tanks having a refrigerant passage extending longitudinally thereof and tube insertion holes communicating with the refrigerant passage, the heat exchanger tubes being joined as inserted through the respective holes to the header tank (see the publication of JP-A No. 2004-3810).

However, when the heat exchanger of the above publication is used as an evaporator, a relatively larger amount of condensation water collects between the top wall of the lower of the tanks and the lower ends of the corrugated fins, and the water is liable to freeze to impair the performance of the evaporator.

An object of the present invention is to overcome the above problem and to provide a heat exchanger which is adapted to reduce the amount of condensation water to be collected on the top wall of a lower tank when the heat exchanger is used as an evaporator.

DISCLOSURE OF THE INVENTION

To fulfill the above object, the present invention comprises the following modes.

1) A heat exchanger comprising a pair of header tanks arranged one above the other at a spacing, a plurality of heat exchange tubes arranged in parallel between the pair of header tanks and having opposite ends joined to the respective header tanks, and fins arranged between respective left-to-right adjacent pairs of heat exchange tubes, the lower header tank comprising a tank forming member and a tube connecting plate joined to an upper surface of the tank forming member, the tube connecting plate having a plurality of drain guides arranged at a spacing in a left-right direction.

2) A heat exchanger according to par. 1) wherein the tube connecting plate has an upper surface cover portion covering the upper surface of the tank forming member and a side cover portion covering at least an upper portion of each of front and rear opposite side faces of the tank forming member, and the drain guides are formed in the upper surface cover portion of the tube connecting plate to the side cover portion thereof.

3) A heat exchanger according to par. 1) wherein the tube connecting plate has an upper surface cover portion covering the upper surface of the tank forming member, and the drain guides are formed in the upper surface cover portion of the tube connecting plate.

4) A heat exchanger according to par. 1) wherein the tube connecting plate has an upper surface cover portion covering the upper surface of the tank forming member and a side cover portion covering at least an upper portion of each of front and rear opposite side faces of the tank forming member, and the drain guides are formed in the side cover portion of the

tube connecting plate.

5) A heat exchanger according to par. 1) wherein the drain guides each comprise a cutout portion formed in the tube connecting plate.

6) A heat exchanger according to par. 1) wherein the drain guides each comprise a recessed portion formed in the tube connecting plate.

7) A heart exchanger according to par. 1) wherein the drain guides each comprise an outwardly protruding rib formed on the tube connecting plate.

8) A heat exchanger according to par. 1) wherein the tank forming member of the lower header tank comprises a header forming plate having at least one outward bulging portion extending longitudinally of the lower header tank, and a closure plate interposed between and joined to the tube connecting plate and the header forming plate so as to close an opening of the outward bulging portion of the header forming plate, and the tube connecting plate has a plurality of tube insertion through holes positioned in corresponding relation with the outward bulging portion and arranged at a spacing longitudinally of the tube connecting plate, the closure plate of the tank forming member having communication through holes for causing the tube insertion holes of the tube connecting plate to communicate with inside of the outward bulging portion of the header forming plate therethrough, the heat exchange tubes having their opposite ends inserted through respective tube insertion holes of tube connecting plates of the two header tanks and brazed to the tube connecting plates.

9) A supercritical refrigeration cycle wherein a supercritical refrigerant is used and which comprises a compressor, a gas cooler, an evaporator, a pressure reducer and an intermediate heat exchanger for subjecting to heat exchange a refrigerant flowing out of the gas cooler and a refrigerant flowing out of the evaporator, the evaporator comprising a heat exchanger according to any one of pars. 1) to 8).

10) A supercritical refrigeration cycle according to par. 9) wherein the supercritical refrigerant is carbon dioxide.

11) A vehicle having installed therein a supercritical refrigeration cycle according to par. 9) as a motor vehicle air conditioner.

When water is produced upon condensation on the surfaces of the corrugated fins arranged between respective adjacent pairs of heat exchange tubes in the heat exchanger according to pars. 1) to 4), the condensation water flowing onto the top surface of the lower tank is led to the front and rear side faces of the lower tank by the drain guides and then falls to below the lower tank. A large amount of condensation water, if collecting between the top surface of the lower tank and the lower ends of the fins, will freeze, whereas this trouble is thus avoidable, consequently preventing the impairment of the performance of the heat exchanger in the case where it is used as an evaporator.

With the heat exchanger according to pars. 5) to 7), the drain guides can be formed relatively easily.

With the heat exchanger according to par. 8), the header

forming plate is provided with an outward bulging portion extending longitudinally of the plate and having its opening closed with the closure plate. This structure eliminates the need for caps for closing opposite end openings of the header tank, consequently reducing the number of components, obviating the need for work to join the caps to the tank and further eliminating the work for making the caps as separate members. The upper header tank is also given the same construction as the lower header tank, and a plurality of outward bulging portions are formed in the header forming plate of at least one of the header tanks. It is then possible to cause the refrigerant to flow through the heat exchanger in a direction suitable to achieve an improved heat exchange efficiency without necessitating any additional member such as a partition.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary perspective view showing the overall construction of a heat exchanger of the invention for use as an evaporator. FIG. 2 is a fragmentary view in vertical section showing the evaporator of FIG. 1 as it is seen from behind toward the front. FIG. 3 is a fragmentary view in section taken along the line A-A in FIG. 2. FIG. 4 is an enlarged fragmentary view in section taken along the line B-B in FIG. 2. FIG. 5 is an exploded perspective view showing a right end portion of an upper header tank of the evaporator of FIG. 1. FIG. 6 is an enlarged fragmentary view in section taken along the line C-C in FIG. 2. FIG. 7 is an exploded perspective view showing the upper header tank of the evaporator of FIG.

1. FIG. 8 is an exploded perspective view showing a lower header tank of the evaporator of FIG. 1. FIG. 9 is a diagram showing the flow of a refrigerant through the evaporator of FIG. 1. FIG. 10 is a fragmentary perspective view showing a first modification of drain guide. FIG. 11 is a fragmentary perspective view showing a second modification of drain guide. FIG. 12 is a fragmentary view in horizontal section showing a third modification of drain guide. FIG. 13 is a fragmentary perspective view showing a fourth modification of drain guide. FIG. 14 is a fragmentary view in horizontal section showing the fourth modification of drain guide. FIG. 15 is a view in cross section showing a first modification of heat exchange tube. FIG. 16 is an enlarged fragmentary view of FIG. 15. FIG. 17 is a diagram showing a process for fabricating the heat exchange tube of FIG. 15. FIG. 18 is a view in cross section showing a second modification of heat exchange tube. FIG. 19 is a view in cross section showing a third modification of heat exchange tube. FIG. 20 is an enlarged fragmentary view of FIG. 19. FIG. 21 is a diagram showing a process for fabricating the heat exchange tube of FIG. 19.

BEST MODE OF CARRYING OUT THE INVENTION

Embodiments of the present invention will be described below with reference to the drawings. This embodiment is a heat exchanger of the invention as adapted for use as an evaporator for supercritical refrigeration cycles.

FIGS. 1 to 3 show the overall construction of the evaporator embodying the invention, FIGS. 4 to 8 show the

constructions of main portions of the evaporator, and FIG. 9 shows the flow of refrigerant through the evaporator of FIG. 1.

With reference to FIGS. 1 to 3, an evaporator 1 for use in supercritical refrigeration cycles wherein a supercritical refrigerant, such as CO_2, is used comprises two header tanks 2, 3 extending in the left-right direction and arranged as spaced part in the upward or downward direction, a plurality of flat heat exchange tubes 4 arranged in parallel in the left-right direction at a spacing between the two header tanks 2, 3, corrugated fins 5 arranged in respective air passing clearances between respective adjacent pairs of heat exchange tubes 4 and outside the heat exchange tubes 4 at the left and right ends of the evaporator and each brazed to the adjacent pair of heat exchange tubes 4 or to the end tube 4, and side plates 6 of aluminum arranged externally of and brazed to the respective fins 34 at the left and right ends.

The upper header tank 2 comprises a tank forming member 7 of aluminum, and a tube connecting plate 8 made from a brazing sheet having a brazing material layer over opposite surfaces thereof, i.e., an aluminum brazing sheet, and brazed to the upwardly or downwardly inner surface, i.e., the lower surface, of the tank forming member 7. The tank forming member 7 comprises a header forming plate 9 made from a brazing sheet having a brazing material layer over opposite surfaces thereof, i.e., an aluminum brazing sheet, and positioned on the upwardly or downwardly outer side, i.e., on the upper side, and a closure plate 10 made of a bare metal material, i.e., a bare aluminum

material and interposed between and brazed to the header forming plate 9 and the tube connecting plate 8.

The header forming plate 9 of tank forming member 7 of the upper header tank 2 has a right portion and a left portion which are provided with two outward bulging portions 12A, 12B and two outward bulging portions 12C, 12D, respectively. The two bulging portions in each of the right and left plate portions extend in the left-right direction and are spaced apart in the front-rear direction. In the present embodiment, the bulging portion 12A in the right front plate portion will be referred to as the "first outward bulging portion," the bulging portion 12B in the right rear plate portion as the "second outward bulging portion," the bulging portion 12C in the left front plate portion as the "third outward bulging portion," and the bulging portion 12D in the left rear plate portion as the "fourth outward bulging portion." The bulging portions 12A to 12D are equal in bulging height, length and width. The first and second outward bulging portions 12A, 12B each serve as a refrigerant passing outward bulging portion for causing CO_2 to flow therethrough longitudinally thereof. The header forming plate 9 is made from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof by press work.

The tube connecting plate 8 of the upper header tank 2 comprises a lower surface cover portion 13 for covering the inner surface, with respect to the upward-downward direction, of the closure plate 10 of the tank forming member 7, i.e., the lower surface thereof, and side cover portions 14 upwardly

projecting from the respective front and rear side edges of the lower surface cover portion 13 integrally therewith and each having an upper end extending to the outer surface of the header forming plate 9 for covering the respective front and rear side faces of the tank forming member 7 over the entire height thereof. The lower surface cover portion 13 is brazed to the bottom surface of the closure plate 10 of the tank forming member 7. The side cover portions 14 are brazed to the front and rear side faces of the header forming plate 9 and the closure plate 10. Each side cover portion 14 is integrally provided at its upper end with a plurality of engaging lugs 16 arranged in the left-right direction at a spacing, engageable with the outer surface of the header forming plate 9 and brazed to the plate 9.

The lower surface cover portion 13 of the tube connecting plate 8 of the upper header tank 2 is provided in each of front and rear opposite side portions thereof with a plurality of tube insertion holes 15 elongated in the front-rear direction, arranged in the left-right direction at a spacing and extending through the thickness of the plate 8. The tube insertion holes 15 in the front right half portion are formed within the left-to-right range of the first outward bulging portion 12A of the header forming plate 9, the tube insertion holes 15 in the rear right half portion are formed within the left-to-right range of the second outward bulging portion 12B, the tube insertion holes 15 in the front left half portion are formed within the left-to-right range of the third outward bulging portion 12C, and the tube insertion holes 15 in the rear left

half portion are formed within the left-to-right range of the fourth outward bulging portion 12D. The tube insertion holes 15 have a length slightly larger than the front-to-rear width of the bulging portions 12A to 12D, and have front and rear end portions projecting outward beyond the respective front and rear side edges of the corresponding bulging portions 12A to 12D (see FIG. 3). The tube connecting plate 8 is made from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof by press work.

The closure plate 10 of tank forming member 7 of the upper header tank 2 has communication holes 17 positioned in corresponding relation with the respective tube insertion holes 15 in the tube connecting plate 8, extending through the thickness thereof and equal in number to the number of tube insertion holes 15 for causing the holes 15 to communicate with one of the outward bulging portions 12A to 12D of the header forming plate 9 therethrough in corresponding relation. The communication holes 17 are substantially larger than the insertion holes 15. The tube insertion holes 15 in the front right half portion of the tube connecting plate 8 are held in communication with the interior of the first outward bulging portion 12A through the communication holes 17 in the front right half portion of the closure plate 10. The tube insertion holes 15 in the rear right half portion of the plate 8 are held in communication with the interior of the second outward bulging portion 12B through the communication holes 17 in the rear right half portion of the closure plate 10. The tube insertion holes 15 in the front left half portion of the plate

8 are held in communication with the interior of the third outward bulging portion 12C through the communication holes 17 in the front left half portion of the closure plate 10. The tube insertion holes 15 in the rear left half portion of the plate 8 are held in communication with the interior of the fourth outward bulging portion 12D through the communication holes 17 in the rear left half portion of the closure plate 10.

The communication holes 17 of the closure plate 10 in communication with the third bulging portion 12C are caused to communicate with the respective communication holes 17 of the plate 10 communicating with the fourth bulging portion 12D by refrigerant turn communication portions 18 formed by cutting away the portions between respective front-to-rear adjacent pairs of communication holes 17 in the closure plate 10, whereby the interior of the third bulging portion 12C and the interior of the fourth bulging portion 12D are caused to communicate with each other (see FIG. 4). All the communication holes 17 communicating with the interior of the first bulging portion 12A, as well as all the communication holes 17 communicating with the interior of the second bulging portion 12B, are held in communication through communication portions 19 formed by removing the portions between respective left-to-right adjacent pairs of communication holes 17 in the closure plate 10 (see FIG. 4). The closure plate 10 is made from a bare aluminum material by press work.

With reference to FIGS. 4 and 5, each of the three plates 8, 9, 10 is provided at the right end thereof with two rightward

projections 8a (9a, 10a) spaced apart in the front-rear direction. The closure plate 10 has cutouts 21A, 21B extending from the outer ends of the front and rear two outward projections 10a to the communication holes 17 at the right end. These cutouts 21A, 21B provide in the upper header tank 2 a refrigerant inlet 22 communicating with the interior of the first outward bulging portion 12A and a refrigerant outlet 23 communicating with the interior of the second outward bulging portion 12B. A refrigerant inlet-outlet member 24 having a refrigerant inflow channel 25 communicating with the refrigerant inlet 22 and a refrigerant outflow channel 26 communicating with the refrigerant outlet 23 is brazed to the upper header tank 2 with a brazing sheet having a brazing material layer over opposite surfaces thereof, i.e., an aluminum brazing sheet 27, so as to be positioned alongside the pairs of rightward projections 8a, 9a, 10a of the three plates 8, 9, 10. The inlet-outlet member 24 is made from a bare metal material, i.e., a bare aluminum material.

The lower header tank 3 comprises a tank forming member 30 of aluminum, and a tube connecting plate 31 made from a brazing sheet having a brazing material layer over opposite surfaces thereof, i.e., an aluminum brazing sheet, and brazed to the upwardly or downwardly inner surface, i.e., the upper surface, of the tank forming member 30. The tank forming member 30 comprises a header forming plate 32 made from a brazing sheet having a brazing material layer over opposite surfaces thereof, i.e., an aluminum brazing sheet, and positioned on the upwardly or downwardly outer side, i.e., on the lower side,

and a closure plate 33 made of a bare metal material, i.e., a bare aluminum material and interposed between and brazed to the header forming plate 32 and the tube connecting plate 31.

The header forming plate 32 of tank forming member 30 of the upper header tank 3 has two outward bulging portions 34A, 34B extending from a right end portion thereof to a left end portion thereof and spaced apart in the front-rear direction so as to be opposed to both the first and third bulging portions 12A, 12C and both the second and fourth bulging portion 12B, 12D, respectively. The bulging portions 34A, 34B are equal in bulging height, length and width. The outward bulging portions 34A, 34B each serve as a refrigerant passing outward bulging portion for causing CO_2 to flow therethrough longitudinally thereof. The header forming plate 32 is made from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof by press work.

The tube connecting plate 31 of the lower header tank 3 comprises an upper surface cover portion 35 for covering the inner surface, with respect to the upward-downward direction, of the closure plate 33 of the tank forming member 30, i.e., the upper surface thereof, and side cover portions 36 downwardly projecting from the respective front and rear side edges of the upper surface cover portion 35 integrally therewith and each having a lower end extending to the outer surface of the header forming plate 32 for covering the respective front and rear side faces of the tank forming member 30 over the entire height thereof. The upper surface cover portion 35 is brazed

to the upper surface of the closure plate 33 of the tank forming member 30. The side cover portions 36 are brazed to the front and rear side faces of the header forming plate 32 and the closure plate 33. Each side cover portion 36 is integrally provided at its lower end with a plurality of engaging lugs 37 arranged in the left-right direction at a spacing, engageable with the outer surface of the header forming plate 32 and brazed to the plate 32.

The upper surface cover portion 35 of the tube connecting plate 31 of the lower header tank 3 is provided in each of front and rear opposite side portions thereof with a plurality of tube insertion holes 38 elongated in the front-rear direction, arranged in the left-right direction at a spacing and extending through the thickness of the plate 31. The front tube insertion holes 38 are formed within the left-to-right range of the front outward bulging portion 34A of the header forming plate 32, and the rear tube insertion holes 38 are formed within the left-to-right range of the rear outward bulging portion 34B. The tube insertion holes 38 have a length slightly larger than the front-to-rear width of the bulging portions 34A, 34B, and have front and rear end portions projecting outward beyond the respective front and rear side edges of the corresponding bulging portion 34A or 34B(see FIGS. 3 and 6). The tube connecting plate 31 is made from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof by press work.

The tube connecting plate 31 has a plurality of drain guides 40 formed therein and arranged in the left-right direction

at a spacing. The guides 40 are formed between the respective left-to-right adjacent pairs of heat exchange tubes 4 and between the side plate 6 and the tube 4 at each of the left and right ends according to the present embodiment, whereas this arrangement is not limitative; the drain guides may be formed at the same position as the respective heat exchange tubes 4 with respect to the left-right direction. Each drain guide 40 comprises a cutout 41 formed by cutting out the tube connecting plate 31 at a front or rear outer side part of the upper surface cover portion 35 to an upper side part of the side cover portion 36. The cutout 41 and the closure plate 33 provide a groove. The part of the cutout 41 formed in the upper surface cover portion 35 is tapered to a pointed end inwardly of the plate 31 with respect to the front-rear direction. Similarly, the part of the cutout 41 formed in the side cover portion 36 is tapered downward to a pointed end.

The closure plate 33 has communication holes 42 positioned in corresponding relation with the respective tube insertion holes 38 in the tube connecting plate 31, extending through the thickness thereof and equal in number to the number of tube insertion holes 38 for causing the holes 38 to communicate with one of the outward bulging portions 34A, 34B of the header forming plate 32 therethrough in corresponding relation. The communication holes 38 are substantially larger than the insertion holes 15. The front tube insertion holes 38 of the tube connecting plate 31 are held in communication with the interior of the front outward bulging portion 34A through the communication holes 42 in the front portion of the closure

plate 33. The rear tube insertion holes 38 of the plate 31 are held in communication with the interior of the rear outward bulging portion 34B through the communication holes 42 in the rear portion of the closure plate 33. All the communication holes 42 in the closure plate 33 communicating with the interior of the front bulging portion 34A, as well as all the communication holes 42 communicating with the interior of the rear bulging portion 12B, are held in communication through communication portions 43 formed by removing the portions between respective left-to-right adjacent pairs of communication holes 42 in the closure plate 33 (see FIG. 6). The closure plate 33 is made from a bare aluminum material by press work.

Between the respective front-to-rear adjacent pairs of tube insertion holes 38 and communication holes 42 of the lower header tank 3, the tube connecting plate 31, closure plate 33 and header forming plate 32 are provided with respective drain holes 44, 45, 46 which are in register with one another, arranged in the left-right direction at a spacing and extending through the thicknesses of the respective plates. The drain holes 44, 45, 46 are formed between the respective left-to-right adjacent pairs of heat exchange tubes 4 and between the side plate 6 and the tube 4 at each of the left and right ends.

The two header tanks 2, 3 are fabricated in the manner shown in FIGS. 7 and 8.

First, an aluminum brazing sheet having a brazing material layer over opposite surfaces is subjected to press work to make for an upper header tank 2 a tube connecting plate 8 which has rightward projections 8a, a lower surface cover portion

13, side cover portions 14, engaging lug forming projections 16A extending straight from each side cover portion 14 and tube insertion holes 15, and for a lower header tank 3 a tube connecting plate 31 which has an upper surface cover portion 33, side cover portions 36, engaging lug forming projections 37A extending straight from each side cover portion 36, tube insertion holes 38, drain guides 40 and drain holes 44. An aluminum brazing sheet having a brazing material layer over opposite surfaces is subjected to press work to make for the upper header tank 2 a header forming plate 9 having rightward projections 9a and outward bulging portions 12A, 12B, 12C, 12D and for the lower header tank 3 a header forming plate 32 having outward bulging portions 34A, 34B and drain holes 46. Further made from a bare aluminum material by press work are a closure plate 10 for the upper header tank 2 which plate has rightward projections 10a, cutouts 21A, 21B, communication holes 17 and communication portions 18, 19, and a closure plate 33 for the lower header tank 3 which plate has communication holes 42, communication portions 43 and drain holes 45.

The three plates 8, 9, 10 and the three plates 31, 32, 33 for the header tanks 2, 3 are then fitted together in superposed layers, respectively, the projections 16A, 37A are bent to make engaging lugs 16, 37, and the lugs 16, 37 are engaged with the respective header forming plates 9, 32 to obtain two tacked assemblies. Utilizing the brazing material layers of the header forming plates 9, 32, the plates 9, 32 are brazed to the closure plates 10, 33 to make tank forming members 7, 30, respectively. Further the brazing material

layers of the header forming plates 9, 32 and the tube connecting plates 8, 31 are utilized to braze the cover portions 13, 35 of the plates 8, 31 to the closure plates 10, 33, to braze the side cover portions 14, 36 to the front and rear side faces of the closure plates 10, 33 and the header forming plates 9, 32, and to braze the engaging lugs 16, 37 to the plates 9, 32. In this way, the two header tanks 2, 3 are fabricated.

Each of the heat exchange tubes 4 is made from a metal extrudate, i.e., an aluminum extrudate in the present embodiment, is in the form of a flat tube having an increased width in the front-rear direction and has inside thereof a plurality of refrigerant channels 4a extending longitudinally thereof and arranged in parallel. The heat exchange tubes 4 are brazed to the tube connecting plates 8, 31 of the two header tanks 2, 3 using the brazing material layers of the plates 8, 31, with their opposite ends placed into the respective tube insertion holes 15, 38 of the tanks 2, 3. Opposite ends of the tube 4 are placed into the communication hole 17, 42 of the closure plates 10, 33 to an intermediate portion of the thickness thereof (see FIG. 3). Between the two header tanks 2, 3, a plurality of tube groups 4A, each comprising a plurality of heat exchange tubes 4 arranged in parallel in the left-right direction at a spacing, are arranged in rows, i.e., in two rows as spaced apart in the front-rear direction. The heat exchange tubes 4 positioned in the right half of the front tube group 4A have upper and lower ends which are joined to the respective header tanks 2, 3 so as to communicate with the interior of the first bulging portion 12A and the interior

of the front bulging portion 34A. The heat exchange tubes 4 positioned in the left half of the front tube group 4A have upper and lower ends which are joined to the respective header tanks 2, 3 so as to communicate with the interior of the third bulging portion 12C and the interior of the front bulging portion 34A. The heat exchange tubes 4 positioned in the right half of the rear tube group 4A have upper and lower ends which are joined to the respective header tanks 2, 3 so as to communicate with the interior of the second bulging portion 12B and the interior of the rear bulging portion 34B. The heat exchange tubes 4 positioned in the left half of the rear tube group 4A have upper and lower ends which are joined to the respective header tanks 2, 3 so as to communicate with the interior of the fourth bulging portion 12D and the interior of the rear bulging portion 34B.

Each of the corrugated fins 5 is made in a wavy form from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. Connecting portions interconnecting crest portions and furrow portions of the fin are provided with a plurality of louvers arranged in parallel in the front-rear direction. The corrugated fin 5 is used in common for the front and rear tube groups 4A and has a front-to-rear width which is approximately equal to the distance from the front edge of heat exchange tube 4 of the front tube group 4A to the rear edge of the corresponding heat exchange tube 4 of the rear tube group 4A. Instead of using one corrugated fin 5 for the front and rear tube groups 4A in common, a corrugated fin may be provided between each adjacent pair of

heat exchange tubes 4 in each of the tube groups 4A.

The evaporator 1 is fabricated by preparing the above-mentioned two tacked assemblies for making two header tanks 2, 3, heat exchanges tubes 4 and corrugated fins 5; arranging the two tacked assemblies as spaced apart with their tube connecting plates 8, 31 opposed to each other; arranging the heat exchange tubes 4 and the corrugated fins 5 alternately; inserting opposite ends of the heat exchange tubes 4 into the respective tube insertion holes 15, 38 of the tube connecting plates 8, 31 of the two tacked assemblies; arranging side plates 6 externally of the respective corrugated fins 5 at opposite ends of the resulting arrangement; placing a refrigerant inlet-outlet member 24 as opposed to all the three plates 8, 9, 10 along with an intervening brazing sheet 27; and brazing the three plates 8, 9, 10 and the three plates 31, 32, 33 of the tacked assemblies to make header tanks 2, 3, and brazing the heat exchange tubes 4 to the header tanks 2, 3, each fin 5 to the heat exchange tubes 4 adjacent thereto, each side plate 6 to the fin 4 adjacent thereto, and the inlet-outlet member 24 to the upper header tank 2 simultaneously with the brazing of each tacked assembly.

The evaporator 1 provides a supercritical refrigeration cycle along with a compressor, gas cooler, pressure reducer and an intermediate heat exchanger for subjecting the refrigerant flowing out from the gas cooler and the refrigerant flowing out from the evaporator to heat exchange, and the refrigeration cycle is installed in vehicles, for example, in motor vehicles, as a motor vehicle air conditioner.

With the evaporator 1 described above, CO_2 reduced in pressure upon passing through a pressure reducer (expansion valve) flows through the refrigerant inflow channel 25 of the inlet-outlet member 24 and through the inlet 22, flows into the first outward bulging portion 12A of the upper header tank 2, flows leftward through the bulging portion 12A, and thereafter flows into the refrigerant channels 4a of all the heat exchange tubes 4 in communication with the interior of the first outward bulging portion 12A as shown in FIG. 9.

The CO_2 flowing into the channels 4a of all the tubes 4 communicating with the interior of the first bulging portion 12A flows down the channels 4a and enters the front outward bulging portion 34A of the lower header tank 3. The CO_2 in the portion 34A flows leftward through this portion 34A and then dividedly flows into the channels 4a of all the heat exchange tubes 4 in communication with the interior of the third outward bulging portion 12C.

The CO_2 in the third bulging portion 12C changes its course, flows upward through the channels 4a and enters the third outward bulging portion 12C of the upper header tank 2. The CO_2 in the bulging portion 12C flows through the refrigerant turn communication portions 18 of the closure plate 10 of the upper header tank 2 into the fourth outward bulging portion 12D, dividedly flows into the channels 4a of all the heat exchange tubes 4 communicating with the fourth bulging portion 12D, changes its course, flows down the channels 4a and enters the rear outward bulging portion 34B of the lower header tank 3. The CO_2 then flows rightward through this portion

34B, dividedly flows into the channels 4a of all the heat exchange tubes 4 communicating with the second outward bulging portion 12B.

The CO_2 in all the heat exchange tubes 4 communicating with the second bulging portion 12B changes its course, flows up through the channels 4a and enters the second outward bulging portion 12B of the upper header tank 2. The CO_2 thereafter flows out of the evaporator 1 via the second bulging portion 12B, the outlet 23 and the outflow channel 26 of the inlet-outlet member 24. While flowing through the channels 4a of the heat exchange tubes 4, the CO_2 is subjected to heat exchange with the air flowing through the air passing clearances in the direction indicated by the arrow X in FIGS. 1 and 9 and flows out from the evaporator in a vapor phase.

At this time, water is produced on the surface of the corrugated fins 5 upon condensation, and the condensation water flows down onto the upper surface of the lower header tank 3. The water on the upper surface of the header tank 3 enters the drain guides 40, flows through the guides 40 and falls off the tank 3 to therebelow from the lower ends of guide portions existing in the side cover portion 36. The condensation water flowing down onto the upper surface of the lower header tank 3 also passes through the drain holes 44, 45, 46 and falls to below the header tank 3. Although a large amount of condensation water will freeze if collecting between the upper surface of the lower header tank 3 and the lower ends of the corrugated fins 5, such trouble is thus avoidable, consequently precluding the impairment of performance of the evaporator

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According to the above embodiment, CO_2 is used as the supercritical refrigerant of the supercritical refrigeration cycle, whereas the refrigerant is not limited to this gas but ethylene, ethane, nitrogen oxide or the like is alternatively used.

FIGS. 10 to 14 show modifications of drain guides for the tube connecting plate 31 of the lower header tank 3.

FIG. 10 shows drain guides 50 each comprising a cutout portion 51 extending in the front-rear direction and formed by cutting out a front or rear outer side part of the upper surface cover portion 35 of the tube connecting plate 31. The cutout portion 51 and the closure plate 33 of the tank forming member 30 provide a groove. The cutout portion 51 has a front or rear outer end having an opening in the outer surface of the side cover portion 36 of the tube connecting plate 31. The cutout portion 51 has a forward or rearward inner end tapered to a pointed extremity inwardly of the plate 31 with respect to the forward or rearward direction.

FIG. 11 shows drain guides 52 each comprising a cutout portion 53 extending downward and formed by cutting out an upper part of the side cover portion 36 of the tube connecting plate 31. The cutout portion 53 and the closure plate 33 of the tank forming member 30 provide a groove. The cutout portion 53 has an upper end with an opening formed in the upper surface of the upper surface cover portion 35 of the tube connecting plate 31. The cutout portion 53 has a downward tapered pointed lower end.

FIG. 12 shows drain guides 54 each comprising a recessed portion 55 extending downward and formed by recessing an upper part of outer surface of the side cover portion 36 of the tube connecting plate 31. The recessed portion 54 has an upper end with an opening formed in the upper surface of the upper surface cover portion 35 of the tube connecting plate 31.

Although not shown, the tube connecting plate 31 may be provided with drain guides each comprising a recessed portion formed at a front or rear outer side part of the upper surface cover portion 35 to an upper part of the side cover portion 36 as is the case with the drain guides of the foregoing embodiment. Like the drain guides shown in FIG. 11, the tube connecting plate 31 may be provided with drain guides each comprising a recessed portion formed in a front or rear outer side part of the upper surface cover portion 35.

FIGS. 13 and 14 show drain guides 56 each comprising an outwardly protruding rib 57 formed by bending the tube connecting plate 31 outward at a front or rear outer part of the upper surface cover portion 35 to an upper part of the side cover portion 36.

Although not shown, the tube connecting plate 31 may be provided with drain guides each comprising an outwardly protruding rib extending forward or rearward and formed by bending the upper surface cover portion 35 outward at a front or rear outer side part, like the drain guides shown in FIG. 10. Further as is the case with the drain guides shown in FIG. 11, the tube connecting plate 31 may be provided with drain guides each comprising an outwardly protruding rib

extending downward and formed by outwardly bending an upper part of the side cover portion 36.

FIGS. 15 to 21 show modified heat exchange tubes for use in the evaporator 1 according to the above embodiment.

FIGS. 15 and 16 show a heat exchange tube 160 which comprises a pair of upper and lower flat walls 161, 162 (a pair of flat walls) opposed to each other, left and right opposite side walls 163, 164 interconnecting the upper and lower walls 161, 162 at their left and right side edges, and a plurality of reinforcing walls 165 interconnecting the upper and lower walls 161, 162 between opposite side walls 163, 164, extending longitudinally of the tube and spaced from one another by a predetermined distance. The tube 160 has in its interior a plurality of refrigerant channels 166 arranged widthwise thereof in parallel. The reinforcing wall 165 serves as a partition wall between each adjacent pair of refrigerant channels 166. The channels 166 are equal in width over the entire height thereof.

The left side wall 163 has a double structure and comprises an outer side wall ridge 167 projecting downward from the left side edge of the upper wall 161 integrally therewith and extending over the entire height of the tube 160, an inner side wall ridge 168 projecting downward from the upper wall 161 integrally therewith and positioned inside the ridge 167, and an inner side wall ridge 169 projecting upward from the left side edge of the lower wall 162 integrally therewith. The outer side wall ridge 167 is brazed to the two inner side wall ridges 168, 169 and to the lower wall 162, with a lower end portion

of the ridge 167 in engagement with a lower surface left side edge of the lower wall 162. The two inner side wall ridges 168, 169 are butted against and brazed to each other. The right side wall 164 is integral with the upper and lower walls 161, 162. The inner side wall ridge 169 of the lower wall 162 is provided on the top end face thereof with a projection 169a extending over the entire length thereof integrally therewith. The inner side wall ridge 168 of the upper wall is provided in the lower end face thereof with a groove 168a extending over the entire length thereof for the projection 169a to be forced in by a press fit.

Each reinforcing wall 165 comprises a reinforcing wall ridge 170 projecting downward from the upper wall 161 integrally therewith, and a reinforcing wall ridge 171 projecting upward from the lower wall 162 integrally therewith, and is formed by butting these ridges 170, 171 against each other and brazing the ridges 170, 171 to each other.

The heat exchange tube 160 is fabricated from a tube making metal plate 175 as shown in FIG. 17(a). The metal plate 175 is made of an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof, and comprises a flat upper wall forming portion 176 (flat wall forming portion), a flat lower wall forming portion 177 (flat wall forming portion), a connecting portion 178 interconnecting the upper and lower wall forming portions 176, 177 for making the right side wall 164, inner side wall ridges 168, 169 integrally projecting upward respectively from the upper wall forming portion 176 and the lower wall forming portion 177 each at a side edge

thereof opposite to the connecting portion 178 for making the inner portion of the left side wall 163, an outer side wall ridge forming portion 179 formed by extending the upper wall forming portion 176 rightwardly outward at a side edge (right side edge) thereof opposite to the connecting portion 178, and a plurality of reinforcing wall ridges 170, 171 projecting upward respectively from the upper wall forming portion 176 and the lower wall forming portion 177 integrally therewith and arranged at a predetermined spacing in the left-right direction. The reinforcing wall ridges 170 on the upper wall forming portion 176 and the reinforcing wall ridges 171 on the lower wall forming portion 177 are symmetrical about a widthwise center line of the connecting portion 178. A projection 169a is formed on the top end of the inner side wall ridge 169 on the lower wall forming portion 177, and a groove 168a is formed in the top end of the inner side ridge 168 on the upper wall forming portion 176. The inner side wall ridges 168, 169 and all the reinforcing wall ridges 70m 171 are equal in height. The vertical thickness of the connecting portion 178 is larger than the thickness of the upper and lower wall forming portions 176, 177, and the upper end face of the connecting portion 178 is substantially flush with the upper end faces of the inner side wall ridges 168, 169 and the reinforcing wall ridges 170, 171.

Since the side wall ridges 168, 169 and the reinforcing wall ridges 170, 171 are formed integrally on one surface of an aluminum brazing sheet which is clad with a brazing material layer over opposite surfaces thereof, a brazing material layer

(not shown) is formed on opposite side faces and the top end faces of the ridges 168, 169 and the ridges 170, 171, and on the upper and lower surfaces of the upper and lower wall forming portions 176, 177. The brazing material layer on the end faces of the ridges 168, 169 and the reinforcing wall ridges 170, 171 has a larger thickness than the brazing material layer on the other portions.

The tube making metal plate 175 is progressively folded at the left and right opposite side edges of the connecting portion 178 by roll forming [see FIG. 17(b)], and is finally folded into a hairpin form to butt the inner side wall ridges 168, 169, as well as each corresponding pair of reinforcing wall ridges 170, 171, against each other and to force the projection 169a into the groove 168a by a press fit.

Subsequently, the outer side wall ridge forming portion 179 is folded onto the outer surface of the inner side wall ridges 168, 169, and the outer end of the portion 179 is deformed into engagement with the lower wall forming portion 177 to obtain a folded body 180 [see FIG. 17(c)].

The folded body 180 is thereafter heated at a predetermined temperature to braze the opposed ends of the inner side wall ridges 168, 169 to each other and the opposed ends of each corresponding pair of reinforcing wall ridges 170, 171 to each other, and the outer side wall ridge forming portion 179 is brazed to the inner side wall ridges 168, 169 and to the lower wall forming portion 177, whereby a heat exchange tube 160 is fabricated. The tube 160 is made simultaneously with the fabrication of the evaporator 1.

FIG. 18 shows a heat exchange tube 185 wherein the end faces of all reinforcing wall ridges 170 on an upper wall 161 are alternately provided with projections 186 extending over the entire length thereof and grooves 187 extending over the entire length thereof. Further the end faces of all reinforcing wall ridges 171 on the lower wall 162 are alternately provided with grooves 188 for the respective projections 186 of the ridges 170 on the upper wall 161 to be butted thereagainst to fit in, and projections 189 to be fitted into the respective grooves 187 in the reinforcing wall ridges 170 on the upper wall 161, the grooves 188 and the projections 189 extending over the entire length of the tube. With the exception of this feature, the tube 185 has the same construction as the tube 160 shown in FIGS. 15 and 16. The tube 185 is fabricated by the same process as the tube 160 shown in FIGS. 15 and 16.

FIGS. 19 and 20 show a heat exchange tube 190, which has reinforcing walls 165 each comprising a reinforcing wall ridge 191 projecting downward from an upper wall 161 integrally therewith and brazed to a lower wall 162, and reinforcing walls 165 each comprising a reinforcing wall ridge 192 projecting upward from the lower wall 162 and brazed to the upper wall 161, the former reinforcing walls 165 and the latter reinforcing wall being arranged alternately in the left-right direction. The portions of one of the upper walls 161, 162 where the reinforcing wall ridges 192 or 191 of the other wall are brought into contact with the wall are each provided with a protrusion 193, the end face of which is provided with a groove 194 for the end of the ridge 191 or 192 to fit in. The end of the

ridge 191 or 192 is fitted in the groove 194 of the protrusion 193 and brazed to the protrusion 193. The left-to-right thickness of the protrusion 193 is slightly larger than the left-to-right thickness of the reinforcing wall ridge 191 or 192. With the exception of the feature described above, the tube 190 has the same construction as the heat exchange tube 160 shown in FIGS. 15 and 16.

The heat exchange tube 90 is fabricated from a tube making metal plate 195 as shown in FIG. 21(a). The metal plate 195 is made of an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof, and comprises a plurality of reinforcing wall ridges 191, 192 projecting upward respectively from an upper wall forming portion 176 and a lower wall forming portion 177 integrally therewith and arranged in the left-right direction at a predetermined spacing. The ridges 191 on the upper wall forming portion 176 and the ridges 192 on the lower wall forming portion 177 are so positioned as to be symmetrical about the widthwise center line of a connecting portion 178. The ridges 191, 192 are equal in height, and the height thereof is approximately twice the height of the side wall ridges 168, 169. The areas of the upper wall forming portion 176 and the lower wall forming portions 177 with which the reinforcing wall ridges 192, 191 of the portions 177 and 176 are brought into contact are each integrally provided with a protrusion 193 extending over the entire length, and a groove 194 is formed in the end of the protrusion 193 for the end of the ridge 192 or 191 to fit in. With the exception of the above feature, the tube making metal plate 195 has the

same construction as the metal plate 175 shown in FIG. 17.

The tube making metal plate 195 is progressively folded at the left and right opposite side edges of the connecting portion 178 by roll forming [see FIG. 21(b)], and is finally folded into a hairpin form to butt the inner side wall ridges 168, 169 against each other to force the projection 169a into the groove 168a by a press fit, and to fit the ends of the reinforcing wall ridges 191 on the upper wall forming portion 176 into the corresponding grooves 194 in the protrusions 193 on the lower wall forming portion 177, and ends of the reinforcing wall ridges 192 on the lower wall forming portion 177 into the corresponding grooves 194 in the protrusions 193 on the upper wall forming portion 176.

Subsequently, the outer side wall ridge forming portion 179 is folded onto the outer surface of the inner side wall ridges 168, 169, and the outer end of the portion 179 is deformed into engagement with the lower wall forming portion 177 to obtain a folded body 196 [see FIG. 21(c)].

The folded body 196 is thereafter heated at a predetermined temperature to braze the opposed ends of the inner side wall ridges 168, 169 to each other and the ends of the reinforcing wall ridges 191, 192 to the protrusions 193, and the outer side wall ridge forming portion 179 is brazed to the inner side wall ridges 168, 169 and to the lower wall forming portion 177, whereby a heat exchange tube 190 is fabricated. The tube 190 is made simultaneously with the fabrication of the evaporator 1.

INDUSTRIAL APPLICABILITY

The heat exchanger of the invention is useful as an evaporator, for example, for use in supercritical refrigeration cycles wherein a supercritical refrigerant, such as CO_2 (carbon dioxide), is used.